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RESEARCH MEMORANDUM

MEASUREMENT OF DISTORTION IN SECOND EXPERIMENTAL CONTROL ROD WITH TEMPERATURE PATTERNS SIMULATING SHIM ROD OUT AND SHIM ROD 50 PERCENT INSERTED FOR ARGONNE NAVAL REACTOR

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Cleveland, Ohio

NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS
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SUMMARY

Thermal distortion tests were made on a stainless-steel clad, cadmium-silver control rod furnished by the Argonne National Laboratory. Two temperature patterns supplied by the Argonne National Laboratory were simulated in these tests; one represented the shim-rod-out condition and the other the shim-rod-50-percent-inserted condition.

The greatest reduction in clearance affected by thermal distortion was 0.076 inch. No permanent set of the control rod was observed after repeated heating and cooling cycles.

INTRODUCTION

Thermal distortion tests were made at the NACA Lewis laboratory on a stainless-steel clad, cadmium-silver core xenon control rod furnished by the Argonne National Laboratory. Distortion measurements on the first experimental control rod with temperatures intended to simulate 50-percent shim-rod insertion are presented in reference 1. Thermal-distortion measurements on a later model xenon rod with temperature patterns simulating operation with shim rods 50 percent inserted and with shim rods out are presented herein. The temperature patterns used as a basis for the tests were obtained from the Argonne laboratory.

EQUIPMENT

Control rod. - The control rod core was made of an alloy of 75-percent silver and 25 percent cadmium and was clad with stainless steel. A cross section of the rod was in the shape of a cross having a span of 4 inches. The core alloy thickness was 1/8 inch with a cladding thickness of 3/64 inch, resulting in a total arm thickness of 7/32 inch. The rod had an over-all length of 53.75 inches. The cladding joints for the tips of the arms and ends of the rod were welded. After fabricating, the rod was hot-rolled in order to form a bond between the core alloy and the stainless steel. The rod was stress relieved.

Several weld failures were found on the rod as received from the Argonne laboratory. Figure 1 shows the most severe failure found. The failures occurred at the welded juncture of the cladding at the tip of the cross at several locations along the length of the rod.

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Method of supporting control rod. - The rod was supported essentially as in reference 1. The vise which holds the control rod, however, was bolted indirectly to the mounting plate through insulating material to reduce the heat flow to the mounting plate. Strain gages were located near the fixed end of the rod to insure freedom from stress during the clamping of the rod in the mounting vise.

Method of obtaining temperature distribution. - The control rod was heated by a 75 KVA induction heater. Axial temperature distributions were obtained by varying the axial spacing of the heater coil turns. Transverse temperature gradients were obtained by making the heating coil and the rod nonconcentric and by a series of air jets mounted along the rod and directed toward the center of the cross. The air jets were provided by 0.0135-inch diameter holes located 3/8 inch apart, and were controllable in groups of 14 by a valve.

Temperature patterns were measured by means of 104 thermocouples distributed between 8 stations located along the axis of the rod as indicated in tables I(a) and II(a) and (b). In addition, thermocouples were located at stations $20\frac{1}{2}$, 21, $21\frac{1}{2}$, $22\frac{1}{2}$, 23, and $23\frac{1}{2}$ inches from the free end of the rod (these positions are adjacent to specific coils of the induction heater) to note any local hot spots due to the proximity of the induction coils. No hot spots at these locations were indicated and the temperatures at these special locations are not reported.

Tables I(a) and II(a) and (b) list the required temperatures at each station as requested by the Argonne laboratory and the measured temperatures in the several runs.

Method of measuring distortion. - Distortion on the rod was measured as in reference 1 by means of dial indicators. Normally two indicators were located at each tip of the cross in positions along the length of rod as given in tables I(b) and II(c) and (d). The indicators were mounted on four vertical supports fastened to the same mounting plate as the control rod (see fig. 2). These supports were protected from conduction and radiation to eliminate thermal distortion in the supports themselves.

Dial indicators were also supplied to indicate any motion of these supports. Fused quartz rods, 12 inches in length, were used to transmit the motion of the control rod to the dial indicators. The use of fused quartz eliminated the need for a correction for thermal expansion of the indicator rods. The reproducibility of the indicator readings was within ±0.002 inch. A vibrator was attached to the mounting plate and was operated before each set of readings was taken to reduce the effect of static friction of the gages.

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RESULTS AND DISCUSSION

Summary of data. - The desired temperature patterns for the tests reported herein were obtained from the Argonne laboratory. Distortion measurements were made with two different temperature patterns; one pattern was intended to simulate operation with the shim rods inserted 50 percent, and one pattern was with the shim rods out. The location of the thermocouples and the corresponding surface temperatures are listed in tables I and II, along with the corresponding distortion measurements. For each thermocouple location, the temperatures desired by the Argonne laboratory and the temperatures experimentally obtained in the present tests are listed. The distance of the thermocouple station from the free end of the rod is represented by Z. The thermocouple locations at each value of Z are designated by numbers from 1 to 16. As indicated in the tables, 16 thermocouples were not installed at each value of Z listed.

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The displacement of the tips of the cross are indicated in tables I and II by the values of Δx and Δy with their proper signs. These values are given with reference to the unheated position of the control rod. The distortion measurements are those corresponding to the temperatures obtained in the tests, which differed slightly from the temperatures desired by the Argonne laboratory.

Distortion of control rod. - The motion of tips 1 and 9 in the y-direction and of tips 5 and 13 in the x-direction are plotted in figures 3 and 4. It would be expected that the sign of the y displacement would always be the same (negative in this case) at the free end, inasmuch as the desired temperatures at location 1 are equal to or higher than those at location 9 in both desired temperature patterns. Figure 3, however, shows Δy to be positive at the free end. Examination of the temperature patterns obtained in table I(a) indicates that near the fixed end of the control rod the temperatures obtained at location 1 were lower than those at location 9 which accounts for the change in direction of displacement. Figure 4 shows Δy to be negative at the free end and inspection of the data in table II(a) indicate that the test temperatures and the desired temperatures agree more closely than in table I. Figure 4(c) and (d) represent the distortion for a slightly different temperature pattern than those in figures 4(a) and (b), the difference being that the fixed end temperatures more nearly matched the required values. The distortions as measured in either case are, however, nearly the same.

The maximum reduction in clearance cannot be determined from figures 3 and 4 alone, inasmuch as the motion of each point in one direction only is shown and hence reference must be made to the tables. It can be seen from the distortion data given in tables I and II that the values for reduction in clearance given in figures 3 and 4, are within 0.002 inch from the maximum. The greatest reduction in clearance obtained in the tests was 0.076 inch as indicated by the data in the tables.

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SUMMARY OF RESULTS

The results of tests on a stainless-steel clad, silver-cadmium control rod under the influence of two temperature patterns which simulated the shim-rod-out condition and the shim-rod-50-percent-inserted condition can be summarized as follows:

1. The greatest reduction in clearance obtained in the tests was 0.076 inch.

2. No permanent set of the control rod was observed after repeated heating and cooling cycles.

Lewis Flight Propulsion Laboratory,
National Advisory Committee for Aeronautics,
Cleveland, Ohio,

REFERENCES

1. Nagey, T. F., and Lietzke, A. F.: Measurement of Distortion in First Experimental Control Rod for Argonne Naval Reactor. NACA RM E51A30, 1951.

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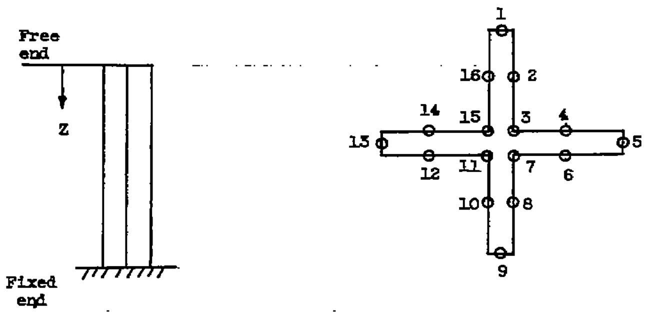
TABLE I - SIMULATED SHIM RODS INSERTED 50 PERCENT.

(a) Temperatures.



Z (in.)	Run	Thermocouple location															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	(a)	476	466	455	463	471	463	455	459	467	459	455	463	471	463	455	466
	1	479	484	484	484	480	480	484	483	479	481	482	482	476	458	485	484
	2	476	481	481	479	476	476	482	480	477	479	479	479	474	434	482	481
8	(a)	525	500	476	492	513	492	476	484	502	484	476	492	513	492	476	500
	1	529				513	509	479	494	504				514	511	482	521
	2	530				515	509	481	494	504				515	512	482	521
15	(a)	509	490	471	484	500	484	471	478	492	478	471	484	500	484	471	490
	1	490	487	470	492	497	494	478	495	504	491		478	479	479	461	487
	2	487	487	470	495	495	495	478	495	506	492		479	480	480	459	487
22	(a)	458	455	452	454	456	454	452	453	455	453	452	454	456	454	452	455
	1	452				449	448	456	451	451				441	443	443	444
	2	450				447	448	447	454	451				438	442	443	441
29	(a)	455	453	451	452	454	452	451	452	453	452	451	452	454	452	451	453
	1	441	446	452	451	449	449	453	455	451	453	455	447	444	445	448	441
	2	436	443	451	448	446	449	452	454	450	452	453	446	436	443	437	436
36	(a)	453	451	450	451	452	451	450	450	451	450	450	451	452	451	450	451
	1	452				458	461	468	476	473				459	464	467	461
	2	445				452	457	465	471	467				452	460	462	459
43	(a)	448	448	448	448	448	448	448	448	448	448	448	448	448	448	448	448
	1	461	470	476	473	467	469	476	481	478	482	482	471	465	467	476	469
	2	456	465	471	468	462	465	473	475	471	478	478	465	460	462	470	463
50	(a)	448	448	448	448	448	448	448	448	448	448	448	448	448	448	448	448
	1	439				436	454	482	490	479				448	465	482	462
	2	425				430	440	473	481	465				435	456	474	451

[a]Requested by Argonne National Laboratory.

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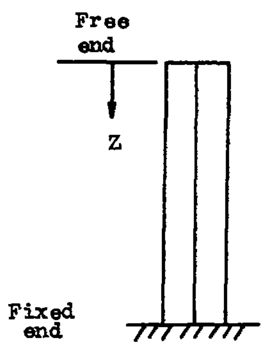
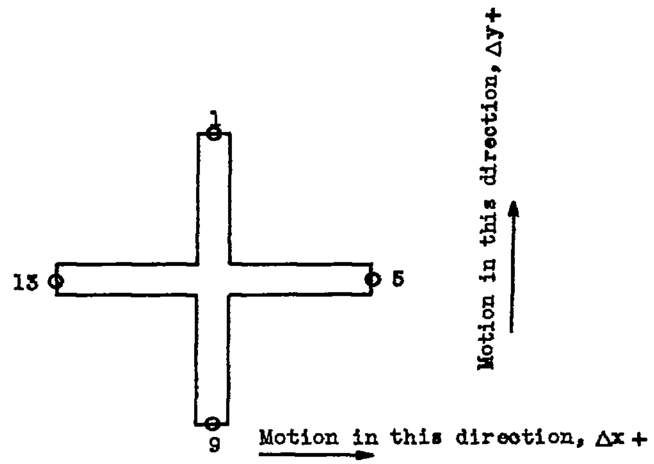
TABLE I - SIMULATED SHIM RODS INSERTED 50 PERCENT. Concluded.

(b) Distortions.





Z (in.)	Run	Displacement (in.)	Gage location 1	5	9	13
2	1	Δx	0.006	0.005	-	-0.027
		Δy	.067	.053	.047	.060
	2	Δx	.004	.007	-	-.027
		Δy	.065	.051	.047	.058
10	1	Δx	-.001	.013	.011	-.011
		Δy	.056	.058	.035	.049
	2	Δx	-.002	.016	.010	-.008
		Δy	.054	.047	.033	.048
20	1	Δx	-.003	.011	-.005	-.002
		Δy	.036	.005	.023	.031
	2	Δx	-.003	.011	-.003	-.001
		Δy	.034	.005	.022	.031
35	1	Δx	-.001	.010	.003	-.006
		Δy	.015	-	-	-
	2	Δx	-.001	.010	0	-.006
		Δy	.013	-	-	-
52	1	Δx	-	-	-	-.005
		Δy	.010	-	-.009	-
	2	Δx	-	-	-	-.004
		Δy	.008	-	-.008	-

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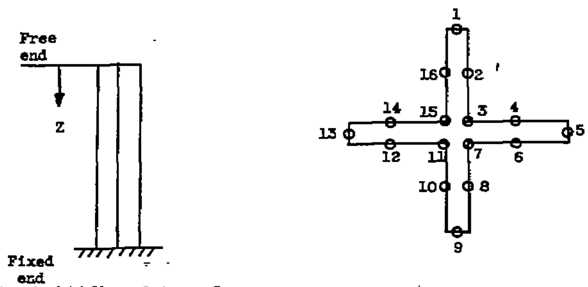
TABLE II - SIMULATED SHIM RODS OUT

(a) Temperatures, runs 1 and 2.



Z (in.)	Run	Thermocouple location															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	(a)	460	455	449	453	458	453	449	451	455	451	449	453	458	453	449	455
	1	459	461	461	461	458	458	459	454	451	449	450	449	437	417	456	460
	2	460	463	464	464	459	459	459	457	451	451	451	450	438	426	457	460
8	(a)	476	466	455	462	470	462	455	459	466	459	455	462	470	462	455	466
	1	480				475	476	456	466	467				464	471	459	480
	2	481				475	475	455	465	467				462	470	468	481
15	(a)	490	476	461	470	482	470	461	466	476	466	461	470	482	470	461	476
	1	493	493	460	479	485	485	446	474	483	478	487	482	483	482	462	488
	2	495	495	465	480	486	487	449	477	486	482		484	485	486	466	489
22	(a)	490	476	461	471	482	471	461	467	476	467	461	471	482	471	461	476
	1	500				487	487	448	470	473				480	480	469	435
	2	503				490	490	451	473	475				482	483	473	445
29	(a)	481	471	459	466	475	466	459	463	471	463	459	466	475	466	459	471
	1	483	485	477	477	473	473	465	474	474	474	469	479	479	480	477	484
	2	485	485	479	479	476	475	457	475	475	475	470	480	480	481	480	485
36	(a)	467	461	454	459	464	459	454	457	461	457	454	459	464	458	454	461
	1	464				462	464	464	459	469				466	466	466	464
	2	465				463	463	465	469	469				466	465	466	466
43	(a)	448	448	448	448	448	448	448	448	448	448	448	448	448	448	448	448
	1	443	444	445	445	448	445	445	445	444	444	446	443	440	440	445	445
	2	446	446	447	448	447	447	448	448	446	446	449	446	444	443	446	446
50	(a)	448	448	448	448	448	448	448	448	448	448	448	448	448	448	448	448
	1	441				441	449	456	446	436				436	447	462	465
	2	449				453	459	469	456	445				445	458	472	478

[a]Requested by Argonne National Laboratory.

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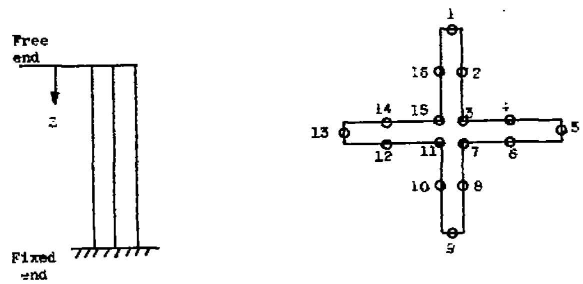
TABLE II - SIMULATED SHIM RODS OUT. Continued

(b) Temperatures; run 3.



Z (in.)	Run	Thermocouple location															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	(a) 3	460 449	455 452	449 450	453 449	458 449	453 451	449 452	451 449	455 444	451 442	449 445	453 444	458 432	453 422	449 448	455 453
8	(a) 3	476 475	466	455	462	470 465	462 466	455 447	459 456	466 457	459	455	462	470	462 458	455 465	466 475
15	(a) 3	490 487	476 487	461 460	470 472	482 478	470 478	461 441	466 467	476 474	465 472	461	470 472	482 472	470 471	461 461	476 473
22	(a) 3	490 491	476	461	471	482 490	471 492	461 450	467 474	476 478	467	461	471	482 480	471 480	461 472	476 444
29	(a) 3	481 489	471 490	459 482	466 481	475 479	466 479	459 469	463 479	471 479	463 475	459 475	466 495	475 485	466 486	459 485	471 490
36	(a) 3	467 462	461	454	459	464 461	459 462	454 465	457 467	461 470	457	454	459	464 467	458 465	454 465	461 461
43	(a) 3	448 441	448 440	448 441	448 441	448 442	448 442	448 441	448 442	448 442	448 443	448 444	448 441	449 440	448 437	448 441	448 440
50	(a) 3	448 450	448	448	448	448 456	448 463	448 469	448 458	448 447	448	448	448	448 448	448 459	448 475	448 480

[a]Requested by Argonne National Laboratory.

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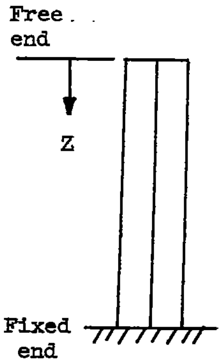
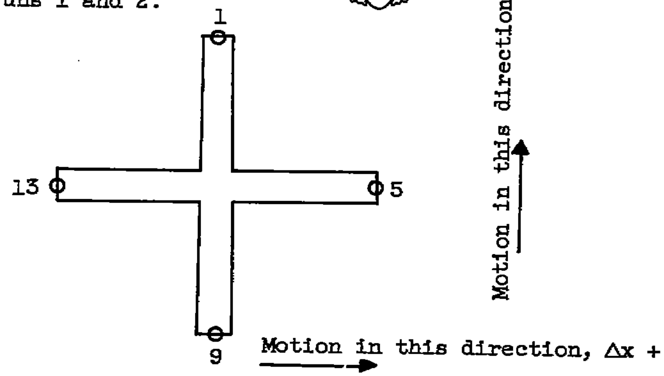
TABLE II - SIMULATED SHIM RODS OUT. Continued

(c) Distortion; runs 1 and 2.





Z (in.)	Run	Displacement (in.)	Gage location 1	5	9	13
2	1	Δx	0.006	0.000	0.006	-0.017
		Δy	-.039	-.052	-.057	-.046
	2	Δx	.005	.002	.006	-.016
		Δy	-.040	-.053	-.058	-.047
10	1	Δx	.007	.005	.013	-.008
		Δy	-.029	-.033	-.043	-.029
	2	Δx	.006	.006	.012	-.007
		Δy	-.030	-.035	-.045	-.030
20	1	Δx	.000	.005	.006	-.008
		Δy	-.008	-.021	-.027	-.032
	2	Δx	-.001	.006	.006	-.008
		Δy	-.009	-.022	-.029	-.033
35	1	Δx	.002	.009	.005	-.007
		Δy	-.003	-.001	-----	-----
	2	Δx	.001	.010	.006	-.007
		Δy	-.004	-.012	-----	-----
52	1	Δx	-----	.007	-----	-.004
		Δy	.002	-----	-.007	-----
	2	Δx	-----	.006	-----	-.004
		Δy	.001	-----	-.007	-----

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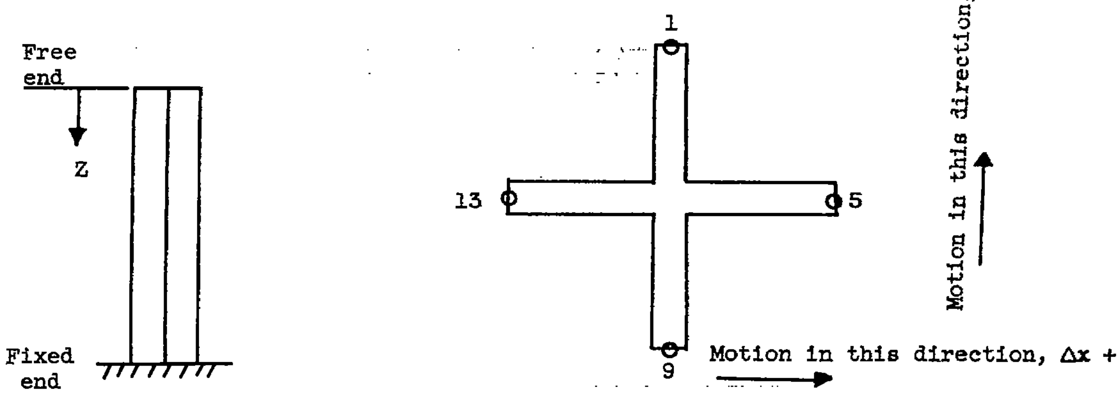
TABLE II - SIMULATED SHIM RODS OUT. Concluded

(d) Distortion; run 3.



Z (in.)	Run	Displacement (in.)	Gage location 1	5	9	13
2	3	Δx Δy	0.002 -.029	0.005 -.048	0.004 -.054	-0.014 -.043
10	3	Δx Δy	.004 -.027	.007 -.031	.011 -.041	-.005 -.027
20	3	Δx Δy	-.002 -.008	.007 -.021	.013 -.027	-.006 -.031
35	3	Δx Δy	.001 -.004	.013 -.010	.012 -----	-.006 -----
52	3	Δx Δy	----- .004	.006 -----	----- -.007	-.003 -----

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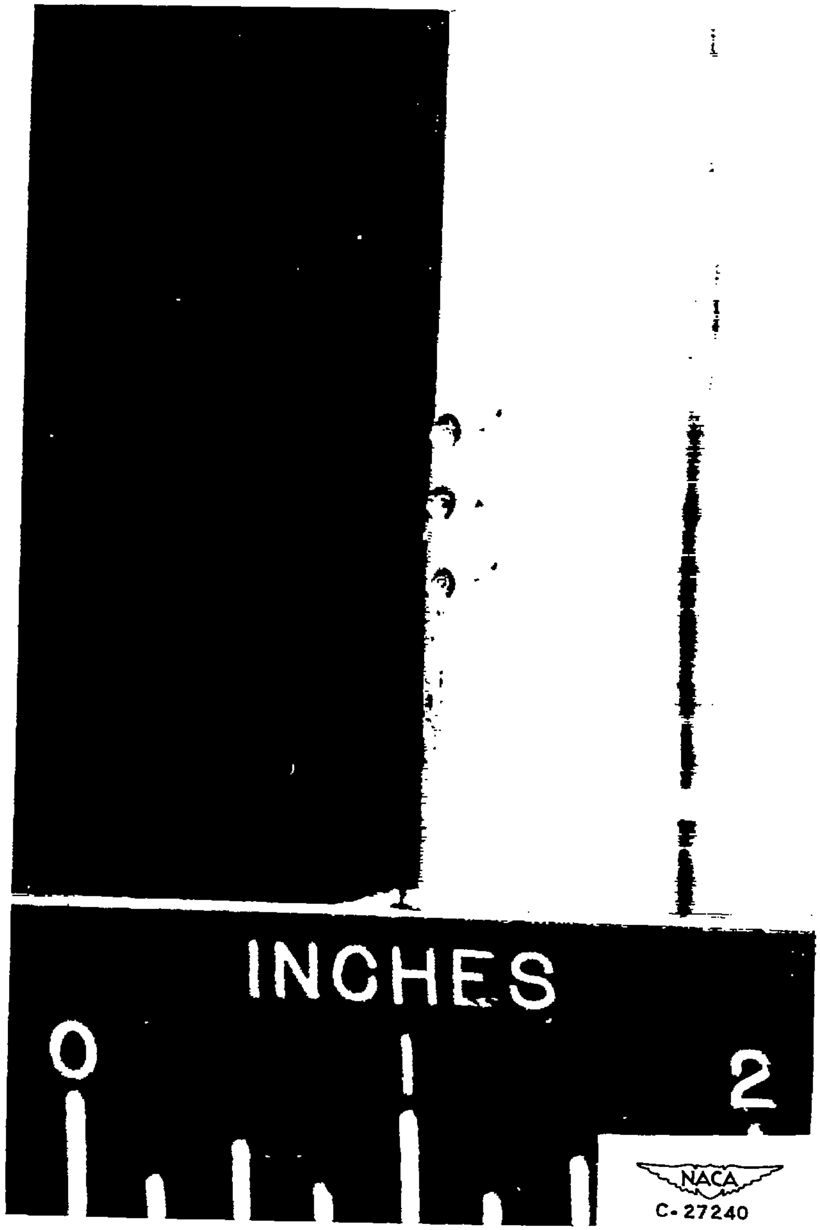

Figure 1. - Photograph of most serious weld failure.

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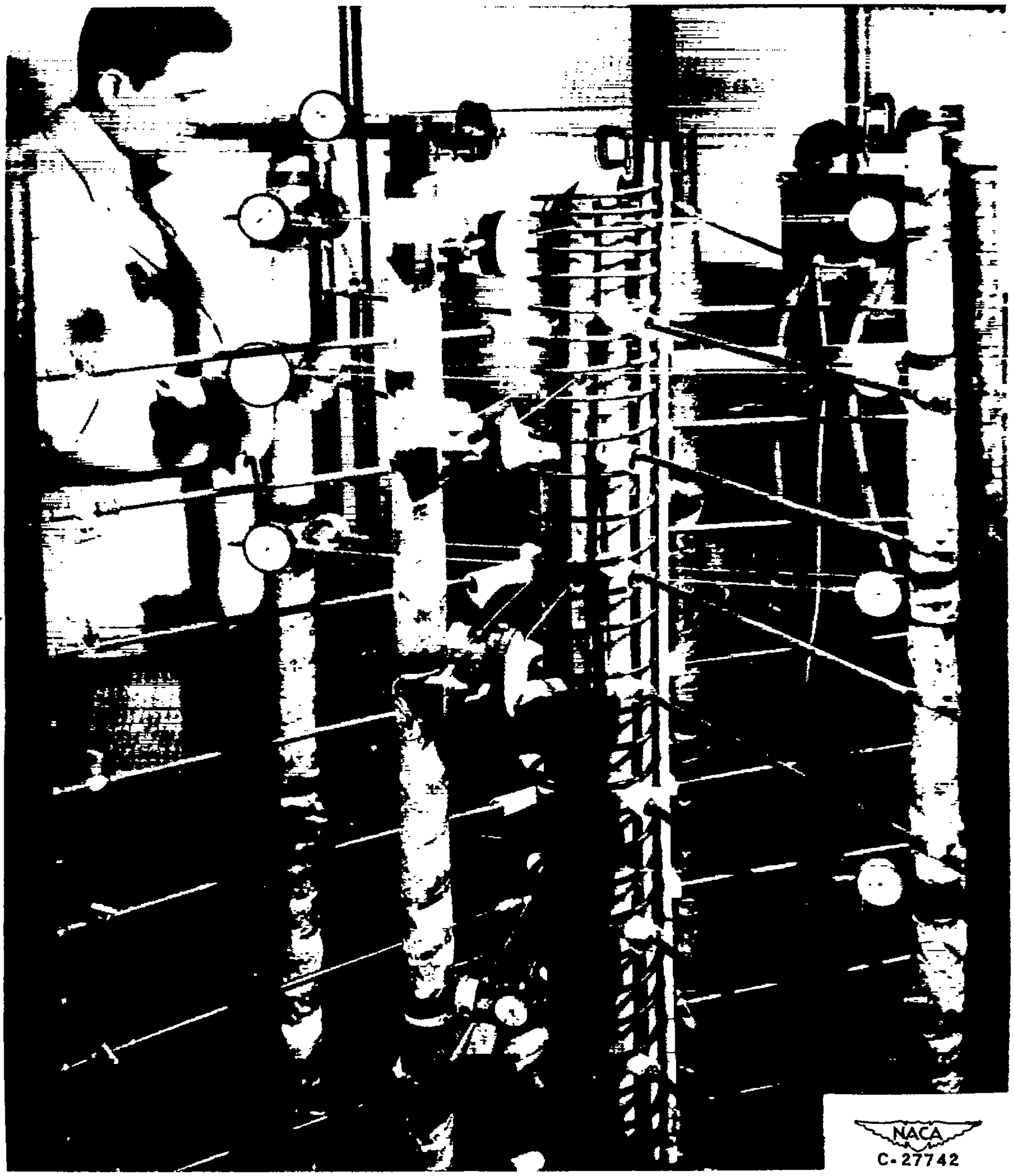
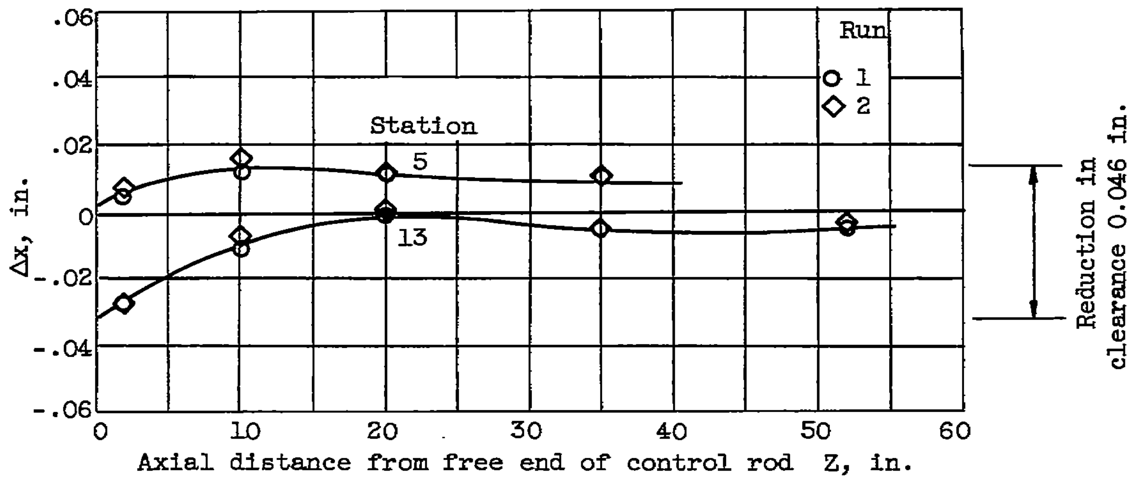
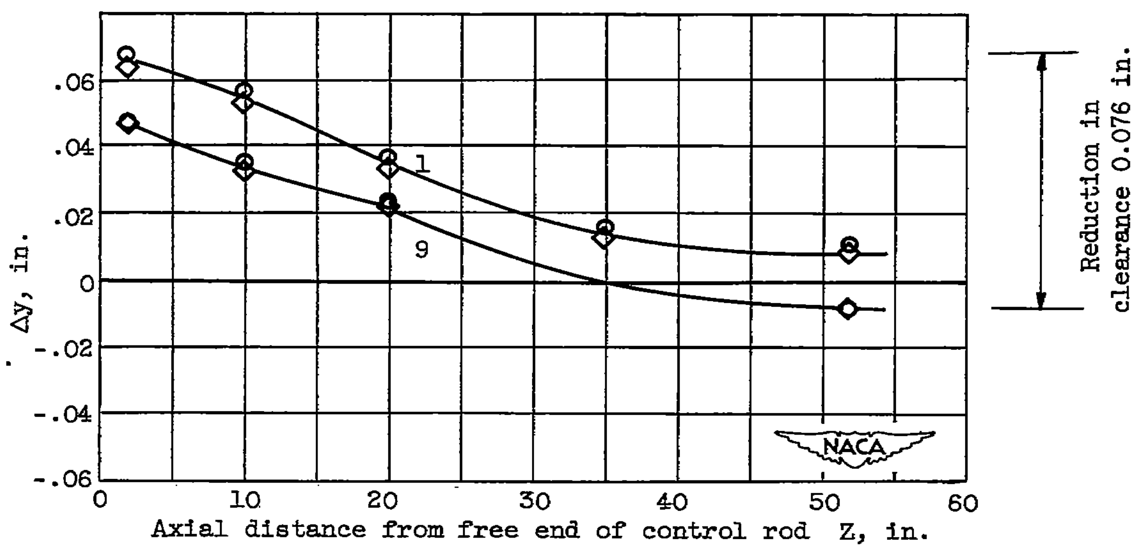


Figure 2. - Photograph of setup.

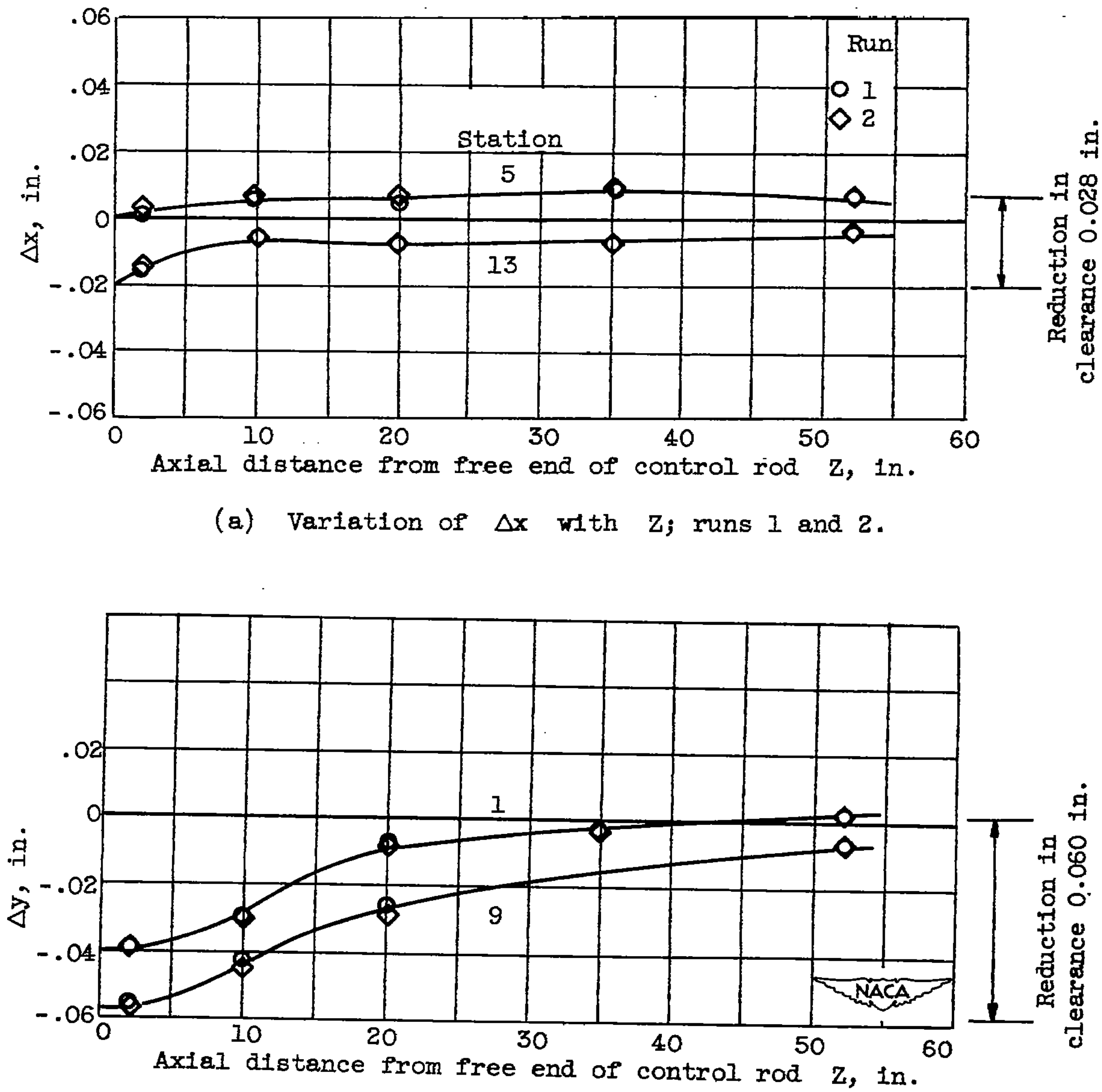


(a) Variation of Δx with Z.



(b) Variation of Δy with Z.

Figure 3. - Distortion of control rod with temperature pattern intended to simulate shim rods inserted 50 percent; normal temperatures.



(a) Variation of Δx with Z; runs 1 and 2.

(b) Variation of Δy with Z; runs 1 and 2.

Figure 4. - Distortion of control rod with temperature pattern intended to simulate shim rods out, normal temperatures.

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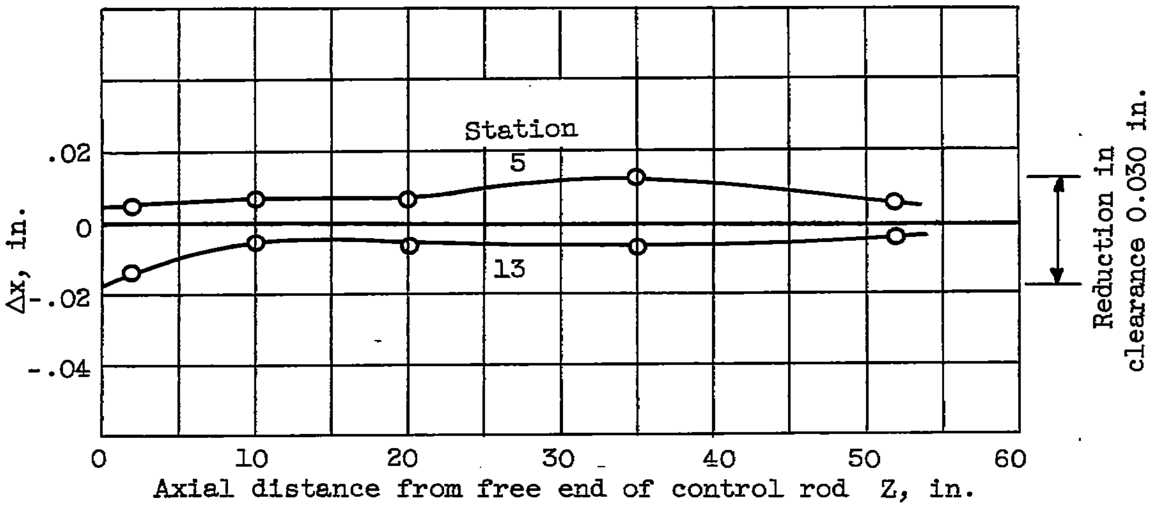
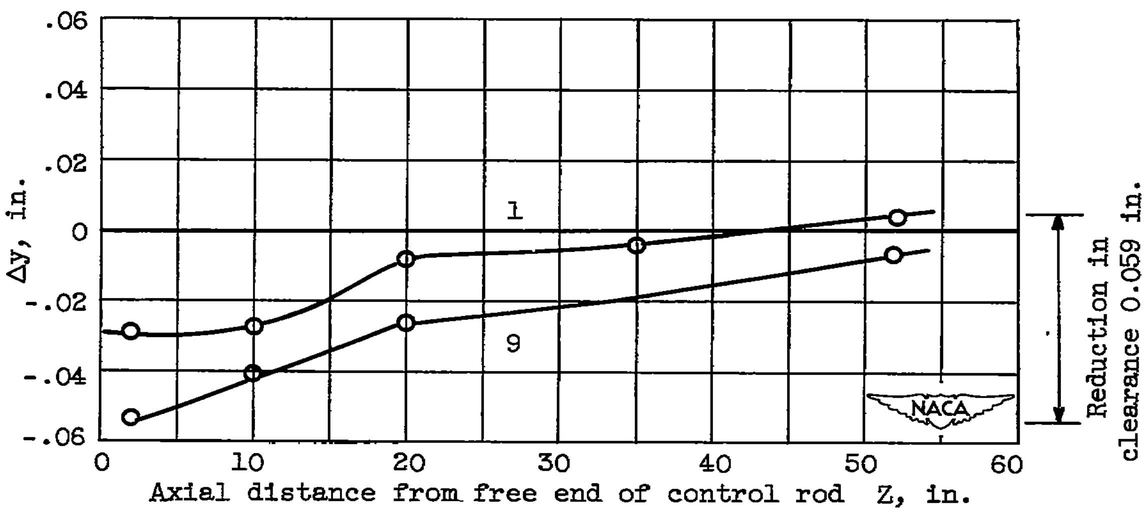


(c) Variation of Δx with Z; run 3.



(d) Variation of Δy with Z; run 3.

Figure 4. - Concluded. Distortion of control rod with temperature pattern intended to simulate shim rods out; normal temperatures.